

## BLACK-NECKED STILT FORAGING SITE SELECTION AND BEHAVIOR IN PUERTO RICO

SEAN A. CULLEN<sup>1</sup>

**ABSTRACT.**—Black-necked Stilts (*Himantopus mexicanus*) in Fraternidad Lagoon, Puerto Rico, foraged in a section of the lagoon that had consistently “deep” water (>9 cm) and the greatest abundance of prey. As wind speed increased, the foraging stilts changed their behavior from a pecking to a sweeping tactic due to the reduced visibility in the water column. Received 26 April 1993, accepted 12 Aug. 1993.

Most studies on the foraging ecology of shorebirds (Order Charadriiformes) have focused on coastal and estuarine systems where tides control the availability of habitat on a daily basis (e.g., papers in Pitelka 1979). Significant associations between the abundance of shorebirds and the density of their main prey have been found (Bryant 1979). However, few studies have focused on habitat use by shorebirds in a tropical or subtropical wintering ground (Robert et al. 1989).

Foraging activity may be affected by environmental factors which influence the birds' behavior or prey availability (Puttick 1984). Tide, rain, substrate permeability, and temperature can affect the foraging behavior of shorebirds (Evans 1979, Goss-Custard 1970, Myers et al. 1980, Pienkowski 1983). Increased wave action caused by wind can reduce availability of prey in shallow water (Evans 1979).

Little is known about the foraging behavior and ecology of Black-necked Stilts (*Himantopus mexicanus*) (Tinarelli 1987, Hamilton 1975). This study explores the relationship between macroinvertebrates and water level to the foraging distribution of the Black-necked Stilt and how wind speed affects stilt foraging behavior in relation to prey availability.

### METHODS

Fraternidad Lagoon (12°30'N, 57°3'W), in the southwest corner of Puerto Rico, is a man-made salt works system which is subdivided into five main areas: Mangrove Pool, “A”, “B”, “Box”, and “C” (Fig. 1). There is an increasing salinity gradient from “Mangrove Pool” to “A” to “B” to “Box” to “C”.

Censuses of Black-necked Stilts in each section were made at least twice a week between 25 September and 14 November 1991. Four people censused the system simultaneously. Transects were established for macroinvertebrate sampling in “Mangrove Pool”, “A”, “B”, and “Box” (Fig. 1). Invertebrate samples were collected eight times at approximately six-day intervals. A sweep net (30 cm × 18 cm, 17 cm deep, 0.5 mm mesh) was used for

<sup>1</sup> Manomet Bird Observatory, P.O. Box 1770, Manomet, Massachusetts 02345, and Dept. of Biology, Queen's Univ., Kingston, Canada, K7L 3N6. (Present address: 131 Briarcliffe Cres, Waterloo, Ont., N2L 5T6.)

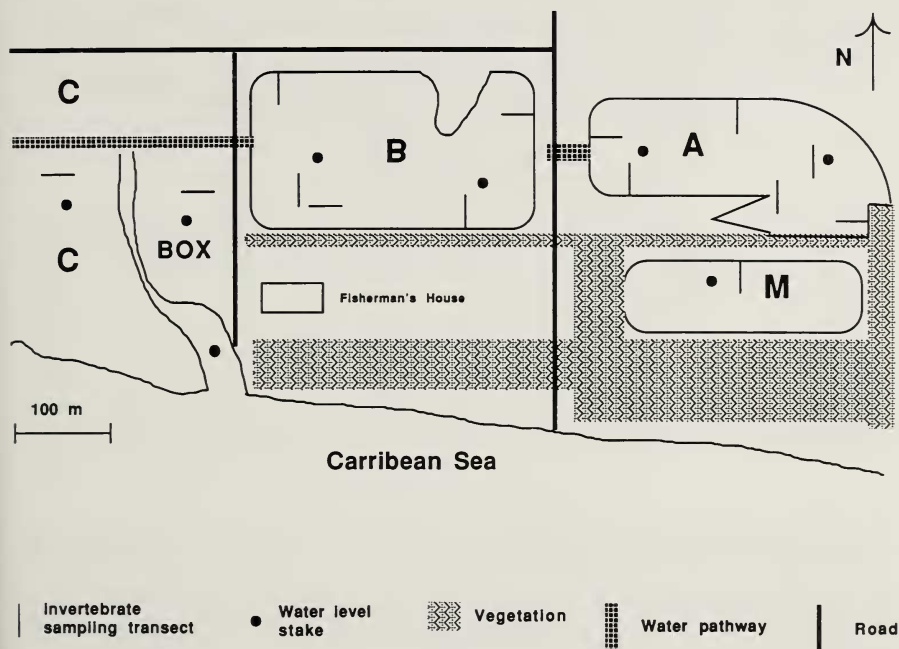


FIG. 1. Map of Fraternidad Lagoon study site.

sampling invertebrates in the water column. The sweep distance was seven steps (approx. 5 m), performed by the same person throughout the study. Along each transect two samples were taken perpendicular to the transect at locations where the water was 6 and 12 cm deep. If the water depth did not reach these levels, the samples were taken as close as possible.

To quantify invertebrate samples, I averaged the estimates made by three persons after washing the sample of the sweep net onto a 0.5 mm screen (35 cm × 31 cm). A size distribution ratio was determined from at least 15% of the sample. Three size categories were used: small (<2.5 mm), medium (2.5–3.5 mm), and large (>3.5 mm). The ratio of large, medium, and small invertebrates was applied to the total for each sweep. All sweeps collected in greater than 9 cm of water were characterized as "deep" and less than 7 cm as "shallow".

Calibrated wooden stakes were placed throughout the Fraternidad System (Fig. 1). By comparing the mean daily water levels to the sweep net data, I was able to determine days when there was "deep" water along the transects.

Behavioral observations were made on foraging Black-necked Stilts. Wind speed, location, water depth, and foraging technique were recorded for each individual. The water depth was divided into five categories according to leg length. Foraging in: 1—no water (0 cm), 2—water at mid-tarsus (5.3 cm), 3—water at tarsometatarsus (10.6 cm), 4—water at mid-tibia (14.2 cm), 5—water at belly (18.3 cm). These water depths were assigned using the mean of leg length measurements of Helmers (1991). Two types of foraging techniques were observed at Fraternidad: pecking and single scythe (Hamilton 1975).

A relationship between wind speed and the percentage of a flock sweeping for each water depth was tested with regression. Analysis of covariance was used to examine the relation-

TABLE 1  
ABUNDANCE OF SIZE CATEGORIES OF WATERBOATMEN IN "DEEP" (>10 CM) AND  
"SHALLOW" (<7 CM) WATER, IN "A", "B" AND "BOX"

|             |    | Waterboatmen category |                 |            |                 |         |                 | Total  |                 |
|-------------|----|-----------------------|-----------------|------------|-----------------|---------|-----------------|--------|-----------------|
|             |    | >3.5 mm               |                 | 2.5–3.5 mm |                 | <2.5 mm |                 |        |                 |
| Location    | N  | Median                | SE <sup>a</sup> | Median     | SE <sup>a</sup> | Median  | SE <sup>a</sup> | Median | SE <sup>a</sup> |
| A deep      | 45 | 291.3                 | 68.7            | 54.6       | 23.8            | 39.1    | 18.9            | 432.0  | 84.5            |
| A shallow   | 31 | 15.1                  | 65.2            | 100.1      | 94.6            | 216.7   | 60.2            | 370.0  | 209.4           |
| B deep      | 11 | 334.6                 | 180.3           | 30.0       | 50.9            | 50.0    | 73.7            | 565.0  | 197.2           |
| B shallow   | 36 | 3.0                   | 63.9            | 2.0        | 34.3            | 36.1    | 37.9            | 47.5   | 159.6           |
| Box deep    | 5  | 37.3                  | 62.2            | 10.8       | 15.2            | 21.0    | 10.9            | 85.5   | 80.0            |
| Box shallow | 4  | 2.0                   | 209.2           | 4.0        | 9.5             | 11.0    | 4.9             | 18.0   | 216.7           |

<sup>a</sup> Standard error.

ship between wind speed, water depth, and the percentage of a flock sweeping, where percent sweeping was the dependent variable, water depth was the classification variable, and wind speed was the continuous variable and covariate of the model. Due to small sample size, I was unable to analyze foraging techniques of Black-necked Stilts foraging in water less than 5.4 cm ( $N = 6$ ). Birds foraging in water deeper than 14.0 cm were grouped together ( $N = 48$ ). All observations of foraging birds were in "A" except for three in "B".

## RESULTS

Black-necked Stilts were observed foraging in eight of the 21 censuses. The mean number of birds using "A" was significantly greater than the number using "B" (Wilcoxon,  $Z = 2.547$ ,  $P = 0.0109$ ,  $N = 8$ ). Over 99% of the Black-necked Stilts observed foraging were in water deeper than 10 cm. A total of 159 sweep net samples were collected throughout the system. Waterboatmen (Order Hemiptera, Family Corixidae) were the only animals caught. Sampling was possible in "C" only once (five waterboatmen captured) since the low water made sampling inappropriate for the rest of the study period. Eight sweeps in "Mangrove" resulted in only 11 waterboatmen (Table 1). There was a significant difference in the number of large waterboatmen among "A deep", "A shallow", "B deep", and "B shallow" categories (Kruskal-Wallis,  $H = 52.029$ ,  $P = 0.0001$ ,  $df = 3$ ). "A deep" and "B deep" had significantly more large waterboatmen than "A shallow" and "B shallow" (Table 2). Total number of waterboatmen differed significantly among "A deep", "A shallow", "B deep", and "B shallow" (Kruskal-Wallis,  $H = 52.029$ ,  $P = 0.0001$ ,  $df = 3$ ). "A deep" and "A shallow" had significantly more waterboatmen than "B shallow" (Table 2). In "B" west, "deep" water was available 58% of the days ( $N = 36$ ). In "B" east, 36% of the days

TABLE 2  
RESULTS OF MANN-WHITNEY U TESTS COMPARING THE ABUNDANCE OF WATERBOATMEN IN  
"A DEEP", "A SHALLOW", "B DEEP", AND "B SHALLOW"<sup>a</sup>

| Locations compared     | Waterboatmen category |       |            |       |         |       | Total |       |
|------------------------|-----------------------|-------|------------|-------|---------|-------|-------|-------|
|                        | >3.5 mm               |       | 2.5-3.5 mm |       | <2.5 mm |       |       |       |
|                        | Z                     | P     | Z          | P     | Z       | P     | Z     | P     |
| A deep vs A shallow    | 4.79                  | .0005 | 1.75       | .0793 | 4.26    | .0006 | 1.00  | .317  |
| A deep vs B deep       | 0.19                  | .8447 | 0.11       | .9097 | 0.68    | .4961 | 0.27  | .7849 |
| A deep vs B shallow    | 6.19                  | .0006 | 4.71       | .0006 | 0.47    | .638  | 5.34  | .0006 |
| A shallow vs B deep    | 2.93                  | .012  | 0.88       | .375  | 2.96    | .0124 | 0.69  | .4865 |
| A shallow vs B shallow | 2.87                  | .008  | 3.28       | .003  | 3.97    | .0005 | 4.08  | .0005 |
| B deep vs B shallow    | 3.87                  | .0004 | 3.31       | .0045 | 0.36    | .7154 | 2.94  | .0132 |

<sup>a</sup> The total number (all size categories combined) of Waterboatmen is also compared between pools. Sequential Bonferroni corrected for table-wide significance (Rice 1989).

(N = 39) had "deep" water. "Deep" water was available every day in "A" (N = 40).

As wind speed increased, the arcsine-transformed percentage of flock members sweeping increased when foraging at a mean water depth of 10.6 cm (Model 1 regression,  $r^2 = 0.453$ ,  $P = 0.0001$ , N = 48) and at a

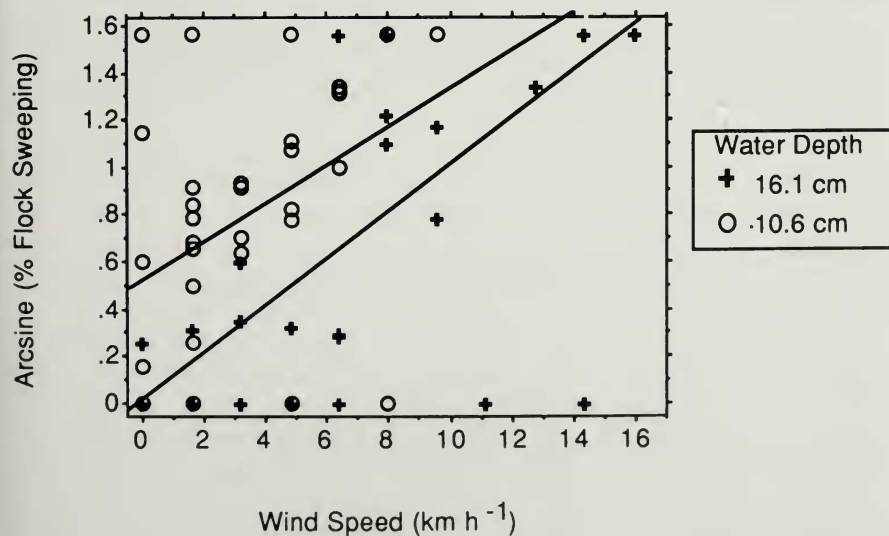


FIG. 2. Regression plot of the arcsine-transformed percentages of stilt flocks sweeping in relation to the wind speed while foraging at mean water depths of 16.1 cm (N = 37) and 10.6 cm (N = 48).

mean water depth of 16.1 cm (Model 1 regression,  $r^2 = 0.14$ ,  $P = 0.0227$ ,  $N = 37$ ) (Fig. 2).

#### DISCUSSION

Waterboatmen, the only invertebrate found in 159 sweeps of the water column, feed on algae and other organic matter (Essig 1942). Black-necked Stilts peck at waterboatmen which come to the surface for air. Visually foraging Black-necked Stilt may focus on areas with the greatest abundance of larger waterboatmen to maximize food intake per catch and perhaps because larger waterboatmen are easier to see.

In sweeping, Black-necked Stilts rely on tactile cues to capture prey (Hamilton 1975). Sweeping Black-necked Stilts could optimize capture of food by foraging in areas with greatest prey abundance and larger prey size (Baker and Baker 1973).

Black-necked Stilts foraged primarily in "A deep" and only rarely elsewhere. They highly favored water deeper than 10 cm. "A deep" is the preferred habitat for stilts in Fraternidad Lagoon. All of the sections beside "A" and "B" had low numbers of prey and were not used as foraging sites (Table 1). "A deep" and "B deep" had a greater average number of large ( $>3.5$  cm) waterboatmen than "A shallow" and "B shallow". "A deep", "B deep", and "A shallow" had the greatest prey abundance. Even though "A shallow" had similar abundance of prey as "A deep" and "B deep", the prey were smaller. Black-necked Stilts appear to prefer the larger prey and greater prey abundance found in deep water. However, stilts foraged in "A deep" significantly more than in "B deep".

Deep water ( $>9$  cm) was available every day in "A" but only 36% and 50% of the days in "B" west end and east end, respectively. Black-necked Stilts would have found deep water in "A" at all times (i.e., abundant large waterboatmen) whereas "B" would typically have shallow water (i.e., few waterboatmen of any size). By foraging in "A deep", stilts were in a location that favored both visual and tactile techniques.

As wind speed increases, a Black-necked Stilt is more likely to sweep instead of peck (Fig. 2). Wind causes waves on the surface of the water. Waves reflect and diffract the sunlight and reduce vision through the water column, making it difficult to locate waterboatmen coming for air (pers. obs.), and causing stilts to switch to tactile feeding.

Attempts were made to determine success rates of pecking and sweeping Black-necked Stilts. Although success rates supposedly can be determined for Black-necked Stilts by counting a jerky swallowing motion following a peck as a success (Tinarelli 1987), I observed birds which had obviously captured a waterboatman but which did not perform jerking



behavior. Their ability to store prey in their bill and/or swallow without a jerking motion made comparisons of the two techniques inappropriate.

#### ACKNOWLEDGMENTS

C. Bower, S. A. Cullen, B. A. Harrington, M. J. Kasprzyk, and P. Pereira collected the invertebrate data, censused shorebirds, and read the water level stakes on a joint project. J. Hagan and C. Naugler provided statistical insight. M. Marciano aided with computer graphics. B. A. Harrington, D. B. Lank, G. Robertson, J. P. Paleczny, and an anonymous reviewer made comments that improved the manuscript. Thanks to the staffs of the Manomet Bird Observatory and the USFW Caribbean Field Station for support in many ways.

#### LITERATURE CITED

- BAKER, M. C. AND E. A. M. BAKER. 1973. Niche relationships among six species of shorebirds on their wintering and breeding ranges. *Ecolog. Monogr.* 43:193-212.
- BRYANT, D. M. 1979. Effects of prey density and site character on estuary usage by overwintering waders (Charadrii). *Est. Coastal Mar. Sci.* 9:369-384.
- ESSIG, E. O. 1942. *College entomology*. MacMillan Co., New York, New York.
- EVANS, P. R. 1979. Adaptations shown by foraging shorebirds to cyclical variations in the activity and availability of their intertidal prey. Pp. 57-94 in *Cyclic phenomena in marine plants and animals* (E. Naylor and R. G. Hartnoll, eds.). Pergamon Press, Toronto, Canada.
- GOSS-CUSTARD, J. D. 1970. Feeding dispersion in some overwintering wading birds. Pp. 3-5 in *Social behaviour in birds and mammals* (J. H. Crook, ed.). Academic Press, New York, New York.
- HAMILTON, R. B. 1975. Comparative behavior of the American Avocet and the Black-necked Stilt (Recurvirostridae). *Ornithol. Monogr.* No. 17.
- HELMERS, D. 1991. Shorebird use of Cheyenne Bottoms. M.S. thesis, Univ. of Missouri, Columbia, Missouri.
- MYERS, J. P., S. L. WILLIAMS, AND F. A. PITELKA. 1980. An experimental analysis of prey availability for sanderlings (Aves: Scolopacidae) feeding on sandy beach crustaceans. *Can. J. Zool.* 58:1564-1574.
- PIENKOWSKI, M. W. 1983. Surface activity of some intertidal invertebrates in relation to temperature and the foraging behaviour of their shorebird predators. *Mar. Ecol. Prog. Ser.* 11:141-150.
- PITELKA, F. A. (ED.). 1979. Shorebirds in marine environments. *Studies Avian Biol.*, No. 2.
- PUTTICK, G. M. 1984. Foraging and activity patterns in wintering shorebirds. Pp. 203-231 in *Behaviour of marine animals*, vol. 6 (J. Burger and B. Olla, eds.). Plenum Press, New York, New York.
- RICE, W. R. 1989. Analyzing tables of statistical tests. *Evolution* 43:223-225.
- ROBERT, M., R. MCNEIL, AND A. LEDUC. 1989. Conditions and significance of night feeding in shorebirds and other water birds in a tropical lagoon. *Auk* 106:94-101.
- TINARELLI, R. 1987. Wintering biology of the Black-winged Stilt in the Mahgreb region. *Wader Study Group Bull.* 50:30-34.